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KAIROMONE RESPONSE IN *Thanasimus* PREDATORS TO PHEROMONE COMPONENTS OF *Ips typographus*

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Abstract—*Thanasimus formicarius* (L.) responds to racemic ipsdienol and ipsenol and less to (*S*)-*cis*-verbenol. All three are pheromone components in several bark beetles of the genus *Ips*. Synergistic effects appeared when the components were combined. Methylbutenol alone, the specific pheromone component of *Ips typographus*, elicited no response, but synergestic effects appeared when methylbutenol was combined with *cis*-verbenol and ipsdienol. The sympatric species *Thanasimus femoralis* (Zett.) responds to (*S*)-*cis*-verbenol, while ipsdienol and ipsenol synergize the response.

Key Words—Kairomone, pheromone, *Thanasimus*, *Ips typographus*, ipsdienol, ipsenol, *cis*-verbenol, methylbutenol, traps, attractant, behavior, Scolytidae, Cleridae.

INTRODUCTION

Pheromones produced by bark beetles are utilized by predacious clerids in order to find the habitat infested by their prey. The chemical messengers of bark beetles act as kairomones for the scolytid predators (Borden, 1977). The clerid species are usually predators on several species of bark beetles, often species of different genera. Most bark beetles have a multicomponent pheromone (Silverstein and Young, 1976), and some components are shared by several species. There is little information available on the mechanisms involved in clerid response to the habitat infested by their prey.

The first discovery of predators utilizing bark beetle pheromones was made by Wood et al. (1968) in California. *Enoclerus lecontei* (Walcott) was captured in field traps baited with *cis*-verbenol, ipsdienol, and ipsenol, the three pheromone components of *Ips paraconfusus* (Lanier). The clerid responded to ipsdienol and ipsenol but *cis*-verbenol failed to elicit a response from the predator. The ternary mixture was the most attractive. *E. lecontei* also responds to *Ips pini* (Say) (Lanier et al., 1972) which has ipsdienol as a pheromone component. *Thanasimus dubius* (F.) and *Thanasimus undatulus* Say are attracted to synthetic frontalin, which is part of the pheromone of several *Dendroctonus* species in North America (Vité and Williamson, 1970; Pitman, 1973; Kline et al., 1974; Dyer et al., 1975). Moser and Brown (1978) captured *T. dubius* in bucket traps baited with a mixture of frontalin and α-pinene, which are used as an attractant for *Dendroctonus frontalis* Zimm.

Thanasimus formicarius (L.) and *T. femoralis* (Zett.) (= *T. rufipes* Brahm) (Biström, 1977) are predators on several species of bark beetles in Europe (Saalas, 1917, p. 435; Gauss, 1954). Both clerids are attracted to the synthetic pheromone components of *Ips typographus* (L.) (Bakke and Kvamme, 1978). Three components are known for the aggregation pheromone of *I. typographus*, i.e., methylbutenol, (*S*)-*cis*-verbenol, and ipsdienol (Bakke et al., 1977; Krawielitzki et al., 1977). Ipsenol is also produced by the male beetle a few days after the excavation of the nuptial chamber (Bakke, 1976), but its behavioral role has not been clarified.

The aim of this paper is to elucidate the response of the two clerid species to the single components of the *I. typographus* pheromone and to their combinations.

METHODS AND MATERIALS

Field experiments were conducted in May and June 1979 in forests at Kongsberg, Lardal, and Eidskog in southern Norway and at Målselv in northern Norway.

The beetles were attracted to traps baited with the pheromone components. Traps were made of black, ridged, cylindrical drainpipes of polyethylene (12.5 × 150 cm) (Figure 1). Each trap had 310 holes (diameter 5 mm) drilled between the ridges. At one end, the pipe was covered with a lid, and at the other end, a funnel with a collecting bottle was mounted.

The traps were placed on a stick in a vertical position with the lower part of the pipe, about 1 m above ground. Distance between the traps was 8–10 m.

Pheromone components known from *I. typographus* were tested alone and in combinations. These were: racemic 2-methyl-6-methylene-2; 7-octadiene-4-ol (ipsdienol), purity 96%; racemic 2-methyl-6-methylene-7-octene-4-ol (ipsenol), purity 94%; (*S*)-*cis*-verbenol, 99% purity, 94% optical purity (all obtained from Borregaard Industries Limited, Sarpsborg, Norway); and 2-methyl-3-butene-2-ol (methylbutenol) (obtained from Aldrich-Europe, Beerse, Belgium).

The dispensers were placed inside the traps in the lower part of the drainpipe. They were made of a polyethylene bag (80 × 60 mm; thickness of polyethylene 0.05 mm) and an absorbant cellulose sheet (40 × 40 × 4 mm).

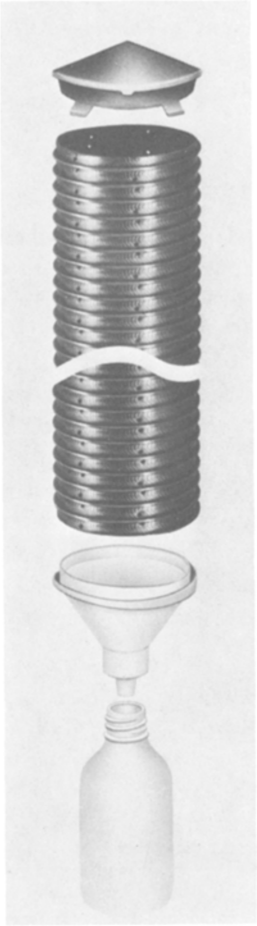

FIG. 1. The drainpipe trap model.

Fifty mg of the pheromone component was added to the cellulose, and it evaporated in small quantities through the polyethylene film. The rate of evaporation, which depends on temperature, was not measured. The temperature in the pipes was approximately 10° C above the air temperature on sunny days, when the beetles fly. The dispensers were still attractive after the termination of the experiments.

A total of 119 traps were used in the experiment. They were set up in the first week of May in southern Norway and in the first week of June in northern Norway. This was before the initial flight of *Thanasimus* spp. The traps were emptied three times during the 4-week experimental period.

In southern Norway we caught a total of 2645 specimens of *T. formicarius* and 158 specimens of *T. femoralis*. In northern Norway we trapped only one specimen (*T. femoralis*). Data from northern Norway are therefore omitted from the analysis.

RESULTS

T. formicarius responded clearly to ipsenol and ipsdienol when these two components were presented individually. (Significance probability ≈ 0.01 for Wilcoxon rank-sum test). A weaker response could be observed to *cis*-verbenol (Tables 1 and 2). Methylbutenol failed to elicit a response (Table 2).

When ipsenol or ipsdienol is combined with *cis*-verbenol, they elicited a response about two times the sum of the responses to the individual components. A synergistic effect could also be seen in the response to ipsdienol plus ipsenol and to the ternary mixture (Table 1). Chi-square analysis revealed that traps with *cis*-verbenol as part of the bait caught significantly more beetles than did traps without *cis*-verbenol ($\chi^2 = 238$, 5 *df*). When methylbutenol was combined with *cis*-verbenol and/or ipsdienol, we noted a significant synergistic effect ($\chi^2 = 34$, 5 *df*).

Only 6.3% of the predators trapped were *T. femoralis*. Despite the low

TABLE 1. *Thanasimus formicarius* AND *Thanasimus femoralis* TRAPPED IN RESPONSE TO VARIOUS PHEROMONE COMPONENTS OF *Ips* SPECIES (KONGSBERG, NORWAY, MAY 20 TO JUNE 4, 1979)

	T. formicarius						*T. femoralis*					
		Test number						Test number				
Test material	Mean	1	2	3	4	5	Mean	1	2	3	4	5
Ipsdienol	16.8	14	18	24	11	17	0.4	0	0	1	0	1
Ipsenol	16.4	20	2	35	11	14	0	0	0	0	0	0
cis-Verbenol	5.8	1	0	16	8	4	1.4	0	1	1	2	3
Ipsdienol + *cis*-verbenol	39.6	37	20	33	58	50	4.4	5	4	0	2	11
Ipsenol + *cis*-verbenol	38.8	21	32	79	22	40	3.2	0	1	0	3	12
Ipsdienol + ipsenol	44.0	73	41	60	13	33	0.8	0	0	1	1	2
Ipsdienol + ipsenol + *cis*-verbenol	103.2	125	198	66	60	67	9.2	4	5	3	3	31
Control	1.8	0	0	4	1	4	0.6	0	0	3	0	0

TABLE 2. *Thanasimus formicarius* AND *Thanasimus femoralis* TRAPPED IN RESPONSE TO VARIOUS PHEROMONE COMPONENTS OF *Ips typographus*[a]

	T. formicarius						*T. femoralis*					
		Test number						Test number				
Test material	Mean	1	2a	2b	3a	3b	Mean	1	2a	2b	3a	3b
Ipsdienol	18.6	15	12	3	28	35	0					
Ipsenol	15.8	19	2	1	15	38	0					
cis-Verbenol	8.8	14	1	4	12	13	1.6	0	0	0	1	7
Ipsdienol + *cis*-verbenol	56.4	45	19	5	77	136	3.0	5	3	0	2	5
Ipsenol + *cis*-verbenol	44.2	23	12	11	80	95	2.6	0	1	1	0	0
Ipsdienol + Ipsenol	20.2	8	24	6	26	37	0					
Methylbutenol	1.8	2	0	0	4	3	0					
Methylbutenol + *cis*-verbenol	16.4	12	0	2	38	30	1.6	0	1	2	0	5
Methylbutenol + ipsdienol	24.8	8	3	8	28	77	0.4	1	0	1	0	0
Methylbutenol + *cis*-verbenol + ipsdienol	43.4	10	12	5	103	87	2.0	1	0	1	6	2
Control	1.8	2	0	0	4	3	0.2	0	0	0	1	0

[a] Means of 5 tests from Lardal (1), Eidskog (2), and Kongsberg (3), May 15 to June 6, 1979.

number, it is possible to see some trends in their response to the pheromone components. Obviously ipsenol and ipsdienol alone or in combination had no attraction, whereas *cis*-verbenol alone appeared to elicit a response (Tables 1 and 2). Ipsenol and/or ipsdienol apparently had a synergistic effect when offered together with *cis*-verbenol. No synergistic effect could be seen when methylbutenol was combined with any of the other pheromone components (Table 2).

The number of beetles trapped varied between the geographical sites. Each trap group caught 71 *Thanasimus* beetles at Eidskog, 176 at Lardal, and 526 at Kongsberg. These differences explain the great variation in range seen in Table 2.

The results indicate a different response in *T. formicarius* and *T. femoralis* to the pheromone components of *Ips*. Ipsenol and ipsdienol are the main kairomonal components for *T. formicarius* and *cis*-verbenol for *T. femoralis*. The synergistic effect of other pheromone components could be observed in both species.

DISCUSSION

Ipsdienol and/or ipsenol, the pheromone components of *I. typographus*, which act as kairomones for *T. formicarius*, are produced by all European species of the genus *Ips* (Table 3). This explains the attraction of the clerid to habitats infested with all *Ips* species (Gauss, 1954).

The trap method may influence some of the results. Traps with methylbutenol as part of the bait always caught some *I. typographus*, while traps without this component caught none. Bark beetles crawling around in the bottle of the trap may release pheromone with their fecal material. The pheromone will evaporate from the bottle through the funnel and into the pipe, and mix with the components of the dispensers. The bait of the traps then could be supplied with the missing pheromone components necessary for the response of the predators.

trans-Verbenol, which is reported from many species of bark beetles (Vité et al., 1972; Francke and Heemann, 1976) has also been used as bait in similar traps (unpublished data). The response of *Thanasimus* spp. to *trans*-verbenol was significantly lower than to *cis*-verbenol. Because of the impurity in the test material (it contained about 10% *cis*-verbenol), the effect of *trans*-verbenol is doubtful.

Most of the pheromone components of bark beetles exist as enantiomers (Silverstein, 1977). The beetles often produce and respond only to one of the enantiomers (Wood et al., 1976; Vité et al., 1978), while the antipode may be inactive, or even strongly inhibitory to the response. The pheromone components used in this field test were all, except (*S*)-*cis*-verbenol, racemic mixtures. Only small amounts of enantiomers of bark beetle pheromones

TABLE 3. PHEROMONE COMPONENTS FROM EUROPEAN SPECIES OF *Ips*[a]

	Ipsdienol	Ipsenol	*cis*-Verbenol	Others	References
I. typographus	PR	P	PR	2-methyl-3-butene-2-ol, PR	Vité et al., 1972 Bakke et al., 1977
I. acuminatus	PR	PR	PR		Bakke, 1978
I. amitinus	P	P	P	*trans*-2-methyl-6-methylen-3,7-octadien-2-ol, "amitinol," P	Francke et al., 1980
I. cembrae	PR	PR		3-methyl-3-butene-1-ol, PR	Stoakley et al., 1978
I. duplicatus	PR				Bakke, 1975
I. sexdentatus	PR	P			Vité et al., 1974

[a] P = produced by the male beetle; R = positive response demonstrated to synthetic components in field tests.

have so far been available for field tests. As far as we know, there are no data available on the response of predators to synthetic enantiomers of bark beetle pheromones.

Predators of bark beetles also respond to volatile substances from host trees. Monoterpenes of conifers attracted *E. lecontei* in California (Rice, 1969) and *T. formicarius* in Czechoslovakia (Rudinsky et al., 1971). We have observed *Thanasimus* spp. in large numbers visiting pine and spruce logs in early spring several days before any bark beetle has started pheromone production. Obviously, the host substances are the olfaction stimuli, guiding the clerids to the logs. No pheromone components of *Ips* are found in *Tomicus piniperda* L. or *T. minor* (Hartig) (Francke and Heemann, 1976), two common bark beetles on pine in Europe and important prey for *T. formicarius* (Saalas, 1917). Either the volatiles from the trees are the only attractants for these bark beetles, or they produce pheromone components not yet identified, which also act as kairomones for these clerids.

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